

7 ESTIMATION OF RELEASE RATES FOR ALTERNATIVE SCENARIOS FOR TOXIC SUBSTANCES

For the alternative scenario analysis, you may use typical meteorological conditions and typical ambient temperature and humidity for your site. This guidance assumes D atmospheric stability and wind speed of 3.0 meters per second (6.7 miles per hour) as conditions likely to be applicable to many sites.

7.1 Release Rates for Toxic Gases

In Section 7.1

- 7.1.1 Methods for unmitigated releases of toxic gases, including:
 - Release of toxic gas from a hole in a tank or pipe (for choked flow conditions, or maximum flow rate),
 - Release of toxic gas from a pipe, based on the flow rate through the pipe, or based on a hole in the pipe (using the same method as for a hole in a tank),
 - Puff releases (no method is provided; users are directed to use other methods),
 - Gases liquefied under pressure, including gaseous releases from holes above the liquid level in the tank and releases from holes in the liquid space, and
 - Consideration of duration of releases of toxic gas.
- 7.1.2 Methods for adjusting the estimated release rate to account for active or passive mitigation, including:
 - Active mitigation to reduce the release duration (e.g., automatic shutoff valves),
 - Active mitigation to reduce the release rate to air, and
 - Passive mitigation (using the same method as for worst-case scenarios).

7.1.1 Unmitigated Releases of Toxic Gases

Gaseous Releases

Gaseous Release from Tank. Instead of assuming release of the entire contents of a vessel containing a toxic gas, you may decide to consider a more likely scenario as developed by the process hazards analysis, such as release from a hole in a vessel or pipe. To estimate a hole size you might assume, for example, the hole size that would result from shearing off a valve or pipe from a vessel containing a regulated substance. If you have a gas leak from a tank, you may use the following simplified equation to estimate a release rate based on hole size, tank pressure, and the properties of the gas. This equation applies to choked flow, or maximum gas flow rate. Choked flow generally would be expected for gases under pressure. (See Appendix D, Section D.6 for the derivation of this equation.)

$$QR = HA \times P_t \times \frac{1}{\sqrt{T_t}} \times GF \quad (7-1)$$

where:	QR	=	Release rate (pounds per minute)
	HA	=	Hole or puncture area (square inches) (from hazard evaluation or best estimate)
	P_t	=	Tank pressure (pounds per square inch absolute (psia)) (from process information; for liquefied gases, equilibrium vapor pressure at 25 °C is included in Exhibit B-1, Appendix B)
	T_t	=	Tank temperature (K), where K is absolute temperature in kelvins; 25 °C (77 °F) is 298 K
	GF	=	Gas Factor, incorporating discharge coefficient, ratio of specific heats, molecular weight, and conversion factors (listed for each regulated toxic gas in Exhibit B-1, Appendix B)

You can estimate the hole area from the size and shape of the hole. For a circular hole, you would use the formula for the area of a circle (area = πr^2 , where π is 3.14 and r is the radius of the circle; the radius is half the diameter).

This equation will give an estimate of the initial release rate. It will overestimate the overall release rate, because it does not take into account the decrease in the release rate as the pressure in the tank decreases. You may use a computer model or another calculation method if you want a more realistic estimate of the release rate. As discussed below, you may use this equation for releases of gases liquefied under pressure if the release would be primarily gas (e.g., if the hole is in the head space of the tank, well above the liquid level).

Example 19. Release of Toxic Gas from Tank (Diborane)

You have a tank that contains diborane gas at a pressure of 30 psia. The temperature of the tank and its contents is 298 K (25 °C). A valve on the side of the tank shears off, leaving a circular hole 2 ½ inches in diameter in the tank wall. You estimate the area from the formula for area of a circle (πr^2 , where r is the radius). The radius of the hole is 1 ¼ inches, so the area is $\pi \times (1 \frac{1}{4})^2$, or 5 square inches. From Exhibit B-1, the Gas Factor for diborane is 17. Therefore, the release rate, from Equation 7-1, is:

$$QR = 5 \times 30 \times 1/(298)^{1/2} \times 17 = 148 \text{ pounds per minute}$$

Gaseous Release from Pipe. If shearing of a pipe may be an alternative scenario for a toxic gas at your site, you could use the usual flow rate through the pipe as the release rate and carry out the estimation of distance as discussed in Chapter 8.

If you want to consider a release of toxic gas through a hole in a pipe as an alternative scenario, you may use the method described above for a gas release from a hole in a tank. This method neglects the effects of friction along the pipe and, therefore, provides a conservative estimate of the release rate.

Puff Releases. If a gaseous release from a hole in a tank or pipe is likely to be stopped very quickly (e.g., by a block valve), resulting in a puff of toxic gas that forms a vapor cloud rather than a plume, you may want to consider other methods for determining a consequence distance. A cloud of toxic gas resulting from a puff release will not exhibit the same behavior as a plume resulting from a longer release (e.g., a release over 10 minutes).

Liquefied Gases

Gases Liquefied Under Pressure. Gases liquefied under pressure may be released as gases, liquids, or a combination (two-phase), depending on a number of factors, including liquid level and the location of the hole relative to the liquid level. The resulting impact distances can vary greatly.

For releases from holes above the liquid level in a tank of gas liquefied under pressure, the release could be primarily gas, or the release may involve rapid vaporization of a fraction of the liquefied gas and possibly aerosolization (two-phase release). It is complex to determine which type of release (i.e., gas, two-phase) will occur and the likely mix of gases and liquids in a two-phase release. The methods presented in this guidance do not definitively address this situation. As a rule of thumb, if the head space is large and the distance between the hole and the liquid level is relatively large given the height of the tank or vessel, you could assume the release is gaseous and, therefore, use Equation 7-1 above. (Exhibit B-1, Appendix B, includes the equilibrium vapor pressure in psia for listed toxic gases liquefied under pressure at 25 °C; this pressure can be used in Equation 7-1.) However, use of this equation will not be conservative if the head space is small and the release from the hole is two-phased. In situations where you are unsure of whether the release would be gaseous or two-phase, you may want to consider other models or methods to carry out a consequence analysis.

For a hole in the liquid space of a tank, you may use Equation 7-2 below to estimate the release rate. Exhibit B-1 in Appendix B gives the equilibrium vapor pressure in psia for listed toxic gases at 25 °C; this is the pressure required to liquefy the gas at this temperature. You can estimate the gauge pressure in the tank from the equilibrium vapor pressure by subtracting the pressure of the ambient atmosphere (14.7 psi). Exhibit B-1 also gives the Density Factor (DF) for each toxic gas at its boiling point. This factor can be used to estimate the density of the liquefied gas (the density at 25 °C would not be significantly different from the density at the boiling point for most of the listed gases). The equation to estimate the release rate is (see Appendix D, Section D.7.1, for more information):

$$QR = HA \times 6.82 \sqrt{\frac{11.7}{DF^2} \times LH + \frac{669}{DF} \times P_g} \quad (7-2)$$

where:	QR	=	Release rate (pounds per minute)
	HA	=	Hole or puncture area (square inches) (from hazard evaluation or best estimate)
	DF	=	Density Factor (listed for each regulated toxic gas in Exhibit B-1, Appendix B; $1/(DF \times 0.033)$ is density in pounds per cubic foot)
	LH	=	Height of liquid column above hole (inches) (from hazard evaluation or best estimate)
	P_g	=	Gauge pressure of the tank pressure (pounds per square inch gauge (psig), from vapor pressure of gas (listed in Exhibit B-1, Appendix B) minus atmospheric pressure (14.7 psi)

This equation gives the rate of release of liquid through the hole. For a gas liquefied under pressure, assume that the released liquid will immediately flash into vapor (or a vapor/aerosol mixture) and the release rate to air is the same as the liquid release rate. This equation gives an estimate of the initial release rate. It will overestimate the overall release rate, because it does not take into account the decrease in the release rate as the pressure in the tank and the height of the liquid in the tank decrease. You may use a computer model or another calculation method if you want a more realistic estimate of the release rate.

For a release from a broken pipe of a gas liquefied under pressure, see equations 7-4 to 7-6 below for liquid releases from pipes. Assume the released liquid flashes into vapor upon release and use the calculated release rate as the release rate to air.

Gases Liquefied by Refrigeration. Gases liquefied by refrigeration alone may be treated as liquids. You may use the methods described in Section 7.2 for estimation of release rates.

Duration of Release

The duration of the release is used in choosing the appropriate generic reference table of distances, as discussed in Chapter 8. (You do not need to consider the duration of the release to use the chemical-specific reference tables.) You may calculate the maximum duration by dividing the quantity in the tank or the quantity that may be released from pipes by your calculated release rate. You may use 60 minutes as a default value for maximum release duration. If you know, and can substantiate, how long it is likely to take to stop the release, you may use that time as the release duration.

7.1.2 Mitigated Releases of Toxic Gases

For gases, passive mitigation may include enclosed spaces, as discussed in Section 3.1.2. Active mitigation for gases, which may be considered in analyzing alternative release scenarios, may include an assortment of techniques including automatic shutoff valves, rapid transfer systems (emergency deinventory), and water/chemical sprays. These mitigation techniques have the effect of reducing either the release rate or the duration of the release, or both.

Active Mitigation

Active Mitigation to Reduce Release Duration. An example of a mitigation technique to reduce the release duration is automatic shutoff valves. If you have an estimate of the rate at which the gas will be released and the time it will take to shut off the release, you may estimate the quantity potentially released (release rate times time). You must be able to substantiate the time it will take to shut off the release. If the release will take place over a period of 10 minutes or more, you may use the release rate to estimate the distance to the toxic endpoint, as discussed in Chapter 8. For releases stopped in less than 10 minutes, multiply the initial release rate by the duration of release to estimate the quantity released, then divide the new quantity by 10 minutes to estimate a mitigated release rate that you may apply to the reference tables described in Chapter 8 to estimate the consequence distance. If the release would be stopped very quickly, you might want to consider other methods that will estimate consequence distances for a puff release.

Active Mitigation to Directly Reduce Release Rate to Air. Examples of mitigation techniques to directly reduce the release rate include scrubbers and flares. Use test data, manufacturer design specifications, or past experience to determine the fractional reduction of the release rate by the mitigation technique. Apply this fraction to the release rate that would have occurred without the mitigation technique. The initial release rate, without mitigation, may be the release rate for the alternative scenario (e.g., a release rate estimated from the equations presented earlier in this section) or the worst-case release rate. The mitigated release rate is:

$$QR_R = (1 - FR) \times QR \quad (7-3)$$

where:

QR_R	=	Reduced release rate (pounds per minute)
FR	=	Fractional reduction resulting from mitigation
QR	=	Release rate without mitigation (pounds per minute)

Example 20. Water Spray Mitigation (Hydrogen Fluoride)

A bleeder valve on a hydrogen fluoride (HF) tank opens, releasing 660 pounds per minute of HF. Water sprays are applied almost immediately. Experimental field and laboratory test data indicate that HF vapors could be reduced by 90 percent. The reduced release rate is:

$$\begin{aligned} QR_R &= (1 - 0.9) \times (660 \text{ pounds per minute}) \\ &= 66 \text{ pounds per minute} \end{aligned}$$

In estimating the consequence distance for this release scenario, you would need to consider the release both before and after application of the water spray and determine which gives the greatest distance to the endpoint. You need to be able to substantiate the time needed to begin the water spray mitigation.

Passive Mitigation

The same simplified method used for worst-case releases may be used for alternative release scenarios to estimate the release rate to the outside air from a release in an enclosed space. For alternative scenarios, you may use a modified release quantity, if appropriate. You may also adjust the mitigation factor to account for the effects of ventilation, if appropriate for the alternative scenario you have chosen. Use the equations presented in Section 3.1.2 to estimate the release rate to the outside air.

Duration of Release

You should estimate the duration of the release either from your knowledge of the length of time it may take to stop the release (be prepared to substantiate your time estimate) or by dividing the quantity that may be released by your estimated release rate. (You do not need to consider the release duration to use the chemical-specific reference tables of distances.)

7.2 Release Rates for Toxic Liquids

In Section 7.2

- 7.2.1 Methods for estimating the liquid release rate and quantity released for toxic liquids released without mitigation, including:
 - Release of toxic liquid from a hole in a tank under atmospheric pressure (including toxic gases liquefied by refrigeration alone),
 - Release of toxic liquid from a hole in the liquid space of a pressurized tank (the user is referred to equations provided in the section on toxic gases or in the technical appendix), and
 - Release of toxic liquid from a broken pipe.
- 7.2.2 Methods for estimating the liquid release rate and quantity released for toxic liquids released with mitigation measures that reduce the duration of the liquid release or the quantity of liquid released (e.g., automatic shutoff valves),
- 7.2.3 Methods for estimating the evaporation rate of toxic liquids from pools, accounting for:
 - Ambient temperature,
 - Elevated temperature,
 - Diked areas,
 - Releases into buildings,
 - Active mitigation to reduce the evaporation rate of the liquid,
 - Temperatures between 25 °C and 50 °C, and
 - Duration of the release.
- 7.2.4 Methods for estimating the evaporation rate for common water solutions of regulated toxic substances and for oleum.

This section describes methods for estimating liquid release rates from tanks and pipes. The released liquid is assumed to form a pool, and the evaporation rate from the pool is estimated as for the worst-case scenario. For the alternative scenario, you may assume the average wind speed in your area in the calculation of evaporation rate, instead of the worst-case wind speed of 1.5 meters per second (3.4 miles per hour). For the reference tables in this guidance, the wind speed for alternative scenarios is assumed to be 3.0 meters per second (6.7 miles per hour).

If you have sufficient information to estimate the quantity of liquid that might be released to an undiked area under an alternative scenario, you may go directly to Section 7.2.3 to estimate the evaporation rate from the pool and the release duration. After you have estimated the evaporation rate and release duration, go to Chapter 8 for instructions on estimating distance to the toxic endpoint.

7.2.1 Liquid Release Rate and Quantity Released for Unmitigated Releases

Release from Tank

Tank under Atmospheric Pressure. If you have a liquid stored in a tank at atmospheric pressure (including gases liquefied by refrigeration alone), you may use the following simple equation to estimate the liquid release rate from a hole in the tank below the liquid level. (See Appendix D, Section D.7.1, for the derivation of this equation.)

$$QR_L = HA \times \sqrt{LH} \times LLF \quad (7-4)$$

where:

QR_L	=	Liquid release rate (pounds per minute)
HA	=	Hole or puncture area (square inches) (from hazard evaluation or best estimate)
LH	=	Height of liquid column above hole (inches) (from hazard evaluation or best estimate)
LLF	=	Liquid Leak Factor incorporating discharge coefficient and liquid density (listed for each toxic liquid in Exhibit B-2, Appendix B).

Remember that this equation only applies to liquids in tanks under atmospheric pressure. This equation will give an overestimate of the release rate, because it does not take into account the decrease in the release rate as the height of the liquid above the hole decreases. You may use a computer model or another calculation method if you want a more realistic estimate of the liquid release rate.

You may estimate the quantity that might be released by multiplying the liquid release rate from the above equation by the time (in minutes) that likely would be needed to stop the release. You should be able to substantiate the time needed to stop the release. Alternatively, you may assume the release would stop when the level of liquid in the tank drops to the level of the hole. You may estimate the quantity of liquid above that level in the tank from the dimensions of the tank, the liquid level at the start of the leak, and the level of the hole. Assume the estimated quantity is released into a pool and use the method and equations in Section 7.2.3 below to determine the evaporation rate of the liquid from the pool and the duration of the release. As discussed in Section 7.2.3, if you find that your estimated evaporation rate is greater than estimated liquid release rate, you should use the liquid release rate as the release rate to air.

Example 21. Liquid Release from Atmospheric Tank (Allyl Alcohol)

You have a tank that contains 20,000 pounds of allyl alcohol at ambient temperature and pressure. A valve on the side of the tank shears, leaving a hole in the tank wall 5 square inches in area. The liquid column is 23 inches above the hole in the tank. From Exhibit B-2, the Liquid Leak Factor for allyl alcohol is 41. Therefore, from Equation 7-4, the liquid release rate is:

$$QR_L = 5 \times (23)^{1/2} \times 41 = 983 \text{ pounds per minute}$$

It takes 10 minutes to stop the release, so 10 minutes \times 983 pounds per minute = 9,830 pounds of allyl alcohol released.

Pressurized Tank. If you have a liquid stored in a tank under pressure, you may estimate a release rate for liquid from a hole in the liquid space of the tank using the equation presented above for gases liquefied under pressure (Equation 7-2 in Section 7.1.1) or the equations in Appendix D, Section D.7.1.

Release from Pipe

If you have a liquid flowing through a pipe at approximately atmospheric pressure, and the pipeline remains at about the same height between the pipe inlet and the pipe break, you can estimate the quantity of liquid released from the flow rate in the pipe and the time it would take to stop the release by multiplying the flow rate by the time. For liquids at atmospheric pressure, assume the liquid is spilled into a pool and use the methods in Section 7.2.3 below to estimate the release rate to air.

For the release of a liquid under pressure from a long pipeline, you may use the equations below (see Appendix D, Section D.7.2 for more information on these equations). These equations apply both to substances that are liquid at ambient conditions and to gases liquefied under pressure. This method does not consider the effects of friction in the pipe. First estimate the initial operational flow velocity of the substance through the pipe using the initial operational flow rate as follows:

$$V_a = \frac{FR \times DF \times 0.033}{A_p} \quad (7-5)$$

where:

V_a	=	Initial operational flow velocity (feet per minute)
FR	=	Initial operational flow rate (pounds per minute)
DF	=	Density Factor (from Exhibit B-2, Appendix B)
A_p	=	Cross-sectional area of pipe (square feet)

You can estimate the cross-sectional area of the pipe from the diameter or radius (half the diameter of the pipe) using the formula for the area of a circle (area = πr^2 , where r is the radius).

The release velocity is then calculated based on the initial operational flow, any gravitational

acceleration or deceleration effects resulting from changes in the height of the pipeline, and the pressure difference between the pressure in the pipe and atmospheric pressure, using a form of the Bernoulli equation:

$$V_b = 197 \times \sqrt{[28.4 \times (P_T - 14.7) \times DF] + [5.97 \times (Z_a - Z_b)] + [2.58 \times 10^{-5} \times V_a^2]} \quad (7-6)$$

where:

V_b	=	Release velocity (feet per minute)
P_T	=	Total pressure on liquid in pipe (psia)
DF	=	Density factor, see Exhibit B-1 or Exhibit B-2
Z_a	=	Height of pipeline at inlet (feet)
Z_b	=	Height of pipeline at break (feet)
V_a	=	Operational velocity (feet per minute), calculated from Equation 7-5

Please note that if the height of the pipe at the release point is higher than the initial pipe height, then $Z_a - Z_b$ is negative, and the height term will cause the estimated release velocity to decrease.

The release velocity can then be used to calculate a release rate as follows:

$$QR_L = \frac{V_b \times A_p}{DF \times 0.033} \quad (7-7)$$

where:

QR_L	=	Release rate (pounds per minute)
V_b	=	Release velocity (feet per minute)
DF	=	Density Factor
A_p	=	Cross-sectional area of pipe (square feet)

You may estimate the quantity released into a pool from the broken pipe by multiplying the liquid release rate (QR_L) from the equation above by the time (in minutes) that likely would be needed to stop the release (or to empty the pipeline). Assume the estimated quantity is released into a pool and use the method and equations described in Section 7.2.3 below to determine the evaporation rate of the liquid from the pool. You must be able to substantiate the time needed to stop the release.

As noted above in Section 7.1.1, for a release from a pipe of gas liquefied under pressure, assume that the released liquid is immediately vaporized, and use the calculated liquid release rate as the release rate to air. If the release duration would be very short (e.g., because of active mitigation measures), determine the total quantity of the release as the release rate times the duration, then estimate a new release rate as the quantity divided by 10. This will give you a release rate that you can use with the 10-minute reference tables of distances in this guidance to estimate a distance to the endpoint.

In the case of very long pipes, release rates from a shear or hole will be lower than the estimates from this method because of pipe roughness and frictional head loss. If friction effects are deemed considerable, an established method for calculating frictional head loss such as the Darcy formula may be used.

7.2.2 Liquid Release Rate and Quantity Released for Mitigated Releases

For alternative release scenarios, you are permitted to take credit for both passive and active mitigation systems, or a combination if both are in place. Active mitigation techniques that reduce the rate of liquid release or the quantity released into the pool are discussed in this section. Active and passive mitigation to reduce the evaporation rate of liquid from a pool are discussed in the next section.

Active Mitigation to Reduce Quantity Released

Examples of mitigation techniques to reduce the quantity released into the pool include automatic shutoff valves and emergency deinventory. You may use the equations in Section 7.2.1 above for calculating liquid release rate, if applicable. Estimate the approximate time needed to stop the release by the mitigation technique (you must be able to justify your estimate). Multiply the release rate times the duration of release to estimate quantity released. Assume the estimated quantity is released into a pool and use the method and equations described in Section 7.2.3 below to determine the evaporation rate of the liquid from the pool. You should also consider mitigation (active or passive) of evaporation from the pool, if applicable, as discussed in Section 7.2.3 below.

Example 22. Mitigated Liquid Release

A bromine injection system suffers a hose failure; the greatly lowered system pressure triggers an automatic shutoff valve within 30 seconds of the release. The flow rate out of the ruptured hose is approximately 330 pounds per minute. Because the release occurred for only 30 seconds (0.5 minutes), the total quantity spilled was 330×0.5 , or 165 pounds.

7.2.3 Evaporation Rate from Liquid Pool

After you have estimated the quantity of liquid released, assume that the liquid forms a pool and calculate the evaporation rate from the pool as described below. You may account for both passive and active mitigation in estimating the release rate. Passive mitigation may include techniques already discussed in Section 3.2.3 such as dikes and trenches. Active mitigation to reduce the release rate of liquid in pools to the air may include an assortment of techniques including foam or tarp coverings and water or chemical sprays. Some methods of accounting for passive and active mitigation are discussed below.

If the calculated evaporation rate from the pool is greater than the liquid release rate you have estimated from the container, no pool would be formed, and calculating the release rate as the evaporation rate from a pool would not be appropriate. If the pool evaporation rate is greater than the liquid release rate, use the liquid release rate as the release rate to air. Consider this possibility particularly for relatively volatile liquids, gases liquefied by refrigeration, or liquids at elevated temperature that form pools with no mitigation.

Unmitigated

Ambient temperature. For pools with no mitigation, if the liquid is always at ambient temperature, find the Liquid Factor Ambient (LFA) and the Density Factor (DF) in Exhibit B-2 of Appendix B (see Appendix D, Section D.2.2 for the derivation of these factors). If your ambient temperature is between 25 °C and 50 °C, you may use this method to calculate the release rate, and then use the appropriate Temperature Correction Factor from Exhibit B-4, Appendix B, to adjust the release rate, as described below. For gases liquefied by refrigeration, use the Liquid Factor Boiling (LFB) and DF from Exhibit B-1. Calculate the release rate from the following equation for liquids at ambient temperature with no mitigation:

$$QR = QS \times 2.4 \times LFA \times DF \quad (7-8)$$

where:

QR	=	Release rate (pounds per minute)
QS	=	Quantity released (pounds)
2.4	=	Wind speed factor = $3.0^{0.78}$, where 3.0 meters per second (6.7 miles per hour) is the wind speed for the alternative scenario for purposes of this guidance
LFA	=	Liquid Factor Ambient
DF	=	Density Factor

This method assumes that the total quantity of liquid released spreads out to form a pool one centimeter in depth; it does not take into account evaporation as the liquid is released.

Example 23. Evaporation from Pool Formed by Liquid Released from Hole in Tank (Allyl Alcohol)

In Example 21, 9,830 pounds of allyl alcohol were estimated to be released from a hole in a tank. From Exhibit B-2, the Density Factor for allyl alcohol is 0.58, and the Liquid Factor Ambient is 0.0046. Assuming that the liquid is not released into a diked area or inside a building, the evaporation rate from the pool of allyl alcohol, from Equation 7-8, is:

$$QR = 9,830 \times 2.4 \times 0.0046 \times 0.58 = 63 \text{ pounds per minute}$$

Elevated temperature. For pools with no mitigation, if the liquid is at an elevated temperature (above 50 °C or at or close to its boiling point), find the Liquid Factor Boiling (LFB) and the Density Factor (DF) in Exhibit B-2 of Appendix B (see Appendix D, Section D.2.2, for the derivation of these factors). For liquids at temperatures between 25 °C and 50 °C, you may use the method above for ambient temperature and apply the appropriate Temperature Correction Factor from Appendix B, Exhibit B-4, to the result, as discussed below. For liquids above 50 °C, or close to their boiling points, or with no Temperature Correction Factors available, calculate the release rate of the liquid from the following equation:

$$QR = QS \times 2.4 \times LFB \times DF \quad (7-9)$$

where:

QR	=	Release rate (pounds per minute)
QS	=	Quantity released (pounds)
2.4	=	Wind speed factor = $3.0^{0.78}$, where 3.0 meters per second (6.7 miles per hour) is the wind speed for the alternative scenario for purposes of this guidance
LFB	=	Liquid Factor Boiling
DF	=	Density Factor

Mitigated

Diked Areas. If the toxic liquid will be released into an area where it will be contained by dikes, compare the diked area to the maximum area of the pool that could be formed, as described in Section 3.2.3 (see Equation 3-6). Also verify that the quantity spilled will be totally contained by the dikes. The smaller of the two areas should be used in determination of the evaporation rate. If the maximum area of the pool is smaller than the diked area, calculate the release rate as described for pools with no mitigation (above). If the diked area is smaller, and the spill will be totally contained, go to Exhibit B-2 in Appendix B to find the Liquid Factor Ambient (LFA), if the liquid is at ambient temperature, or the Liquid Factor Boiling (LFB), if the liquid is at an elevated temperature. For temperatures between 25 °C and 50 °C, you may use the appropriate Temperature Correction Factor from Exhibit B-4, Appendix B, to adjust the release rate, as described below. For gases liquefied by refrigeration, use the LFB. Calculate the release rate from the diked area as follows for liquids at ambient temperature:

$$QR = 2.4 \times LFA \times A \quad (7-10)$$

or, for liquids at elevated temperatures or gases liquefied by refrigeration alone:

$$QR = 2.4 \times LFB \times A \quad (7-11)$$

where:

QR	=	Release rate (pounds per minute)
2.4	=	Wind speed factor = $3.0^{0.78}$, where 3.0 meters per second (6.7 miles per hour) is the wind speed for the alternative scenario for purposes of this guidance
LFA	=	Liquid Factor Ambient (listed in Exhibit B-2, Appendix B)
LFB	=	Liquid Factor Boiling (listed in Exhibit B-1 or B-2, Appendix B)
A	=	Diked area (square feet)

Releases Into Buildings. If a toxic liquid is released inside a building, compare the area of the building floor or any diked area that would contain the spill to the maximum area of the pool that could be formed; the smaller of the two areas should be used in determining the evaporation rate, as for the worst-case scenario. The maximum area of the pool is determined from Equation 3-6 in Section 3.2.3 for releases into diked areas. The area of the building floor is the length times width of the floor (in feet) (Equation 3-9).

If the floor area or diked area is smaller than the maximum pool size, estimate the outdoor evaporation rate from a pool the size of the floor area or diked area from Equation 7-10. If the maximum pool area is smaller, estimate the outdoor evaporation rate from a pool of maximum size from Equation 7-8.

Estimate the rate of release of the toxic vapor from the building as five percent of the calculated outdoor evaporation rate (multiply your evaporation rate by 0.05). See Appendix D, Section D.2.4 for more information on releases into buildings.

Active Mitigation to Reduce Evaporation Rate. Examples of active mitigation techniques to reduce the evaporation rate from the pool include water sprays and foam or tarp covering. Use test data, manufacturer design specifications, or past experience to determine the fractional reduction of the release rate by the mitigation technique. Apply this fraction to the release rate (evaporation rate from the pool) that would have occurred without the mitigation technique, as follows:

$$QR_{RV} = (1 - FR) \times QR \quad (7-12)$$

where:

QR_{RV}	=	Reduced evaporation rate (release rate to air) from pool (pounds per minute)
FR	=	Fractional reduction resulting from mitigation
QR	=	Evaporation rate from pool without mitigation (pounds per minute)

Temperature Corrections for Liquids at Temperatures between 25 and 50 °C

If your liquid is at a temperature between 25 °C (77 °F) and 50 °C (122 °F), you may use the appropriate Temperature Correction Factor (TCF) from Exhibit B-4, Appendix B, to calculate a corrected release rate. Calculate the release rate (QR) of the liquid at 25 °C (77 °F) as described above for unmitigated releases or releases in diked areas and multiply the release rate by the appropriate TCF as described in Section 3.2.5.

Evaporation Rate Compared to Liquid Release Rate

If you estimated the quantity of liquid in the pool based on an estimated liquid release rate from a hole in a container or pipe, as discussed in Sections 7.2.1 and 7.2.2, compare the evaporation rate with the liquid release rate. If the evaporation rate from the pool is greater than the liquid release rate, use the liquid release rate as the release rate to air.

Duration of Release

After you have estimated a release rate as described above, determine the duration of the vapor release from the pool (the time it will take for the liquid pool to evaporate completely). To estimate the time in minutes, divide the total quantity released (in pounds) by the release rate (in pounds per minute) (see Equation 3-5 in Section 3.2.2). If you are using the liquid release rate as the release rate to air, as discussed in the preceding paragraph, estimate a liquid release duration as discussed in Section 7.2.1 or 7.2.2. The duration could be the time it would take to stop the release or the time it would take to empty the tank or to release all the liquid above the level of the leak. If you have corrected the release rate for a temperatures above 25 °C, use the corrected release rate to estimate the duration.

7.2.4 Common Water Solutions and Oleum

You may use the methods described above in Sections 7.2.1, 7.2.2, and 7.2.3 for pure liquids to estimate the quantity of a solution of a toxic substance or oleum that may be spilled into a pool. LFA, DF, and LLF values for several concentrations of ammonia, formaldehyde, hydrochloric acid, hydrofluoric acid, and nitric acid in water solution and for oleum are listed in Appendix B, Exhibit B-3. The LFA for a wind speed of 3.0 meters per second (6.7 miles per hour) should be used in the release rate calculations for alternative scenarios for pools of solutions at ambient temperature.

For unmitigated releases or releases with passive mitigation, follow the instructions in Section 7.2.3. If active mitigation measures are in place, you may estimate a reduced release rate from the instructions on active mitigation in Section 7.2.2. Use the total quantity of the solution as the quantity released from the vessel or pipeline (QS) in carrying out the calculation of the release rate to the atmosphere.

If the solution is at an elevated temperature, see Section 3.3. As discussed in Section 3.3, you may treat the release of the substance in solution as a release of the pure substance. Alternatively, if you have vapor pressure data for the solution at the release temperature, you may estimate the release rate from the equations in Appendix D, Sections D.2.1 and D.2.2.

If you estimated the quantity of solution in the pool based on an estimated liquid release rate from a hole in a container or pipe, as discussed in Sections 7.2.1 and 7.2.2, compare the evaporation rate with the liquid release rate. If the evaporation rate from the pool is greater than the liquid release rate, use the liquid release rate as the release rate to air.